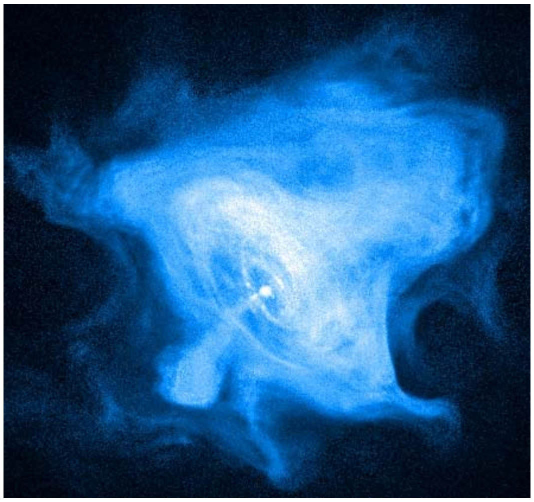
The Crab Nebula - Exploring a pulsar up close!



The Crab Nebula is all that remains of a massive star that exploded as a supernova, and was seen by humans for the first time in 1054 AD. Located 6000 light years away, it is still being powered by a rapidly-spinning neutron star.

The electromagnetic energy from this spinning, magnetized object (also called a pulsar) produces the amazing high-energy cloud of particles now seen clearly by the NASA, Chandra Observatory in the image to the left.

This image gives the first clear view of the faint boundary of the Crab Nebula's X-ray-emitting pulsar wind nebula. The combination of rapid rotating and strong magnetic field generates an intense electromagnetic field that creates jets of matter and anti-matter moving away from the north and south poles of the pulsar, and an intense wind flowing out in the equatorial direction.

The inner X-ray ring is thought to be a shock wave that marks the boundary between the surrounding nebula and the flow of matter from the pulsar. Energetic electrons and positrons (a form of antimatter) move outward from this ring to produce an X-ray glow that Chandra sees as a ghostly cloud in the image above.

Problem 1 - The width of this image is about 5 light years. If the elliptical ring near the center is actually a circular ring seen at a tilted angle, what is the radius of this ting in: A) light years? B) kilometers? (Note: 1 light year = 5.9 trillion kilometers).

Problem 2 - The high-energy particles that make-up the ring were created near the neutron star at the center of the ring. If they are traveling at a speed of 95% the speed of light, to the nearest day, how many days did it take for the particles to reach the edge of the ring? (Speed of light = 300,000 km/s)

Problem 3 - Suppose the pulsar ejected the particles and was visible to astronomers on Earth as a burst of light from the central neutron star 'dot'. If the astronomers wanted to see the high-energy particles from this ejection reach the ring and change its shape, how long would they have to wait for the ring to change after seeing the burst of light?

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Answer: the scale of this image can be found using a millimeter ruler. When printed, the image is about 70 mm. The scale is then 5 ly/70mm = 0.071 ly/mm. The radius of the ring will be the maximum radius of the elliptical ring, which you can see by drawing a circle on a piece of paper and tilting it so it looks like an ellipse. On the image, the length of the major axis of the ellipse is 10 mm, so the radius of the circle is 5 mm.
A) Using the scale of the image we get 5 mm x 0.071 ly/mm = **0.36 light years.**
B) The radius in kilometers is just 0.36 ly x 5.9 trillion km/1 ly = **2.1 trillion km.**

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Answer: Time = distance/speed, so for s = 0.95x300,000 km/s = 285,000 km/s, and d = 2.1 trillion km, we get T = 2,100,000,000,000 / 285,000 = 7,368,421 seconds. Converting to days: 7,368,421 seconds x (1 hour/3600 sec) x (1 day/24 hours) = 85.28 days. To the nearest day, this is 85 days.

Problem 3 - Suppose the pulsar ejected the particles and was visible to astronomers on Earth as a burst of light from the central neutron star 'dot'. If the astronomers wanted to see the high-energy particles from this ejection reach the ring and change its shape, how long would they have to wait for the ring to change after seeing the burst of light?

Answer; They would have to wait 85 days after seeing the burst of light because light travels faster than the matter in the particles.

Note: Another way to appreciate how much faster light travels, calculate the number of days it would take for the pulse of light to reach the ring, compared to the 85 days taken by the particles. The light pulse would take 2.1 trillion km/300,000 km/s = 7 million seconds or about 81 days. So astronomers would have to wait 81 days to see whether the light pulse affects the ring, and then another 4 days for the particles to arrive.